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October 27, 2003

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APPLICATION NUMBER: *60/412,778*
FILING DATE: *September 24, 2002*
RELATED PCT APPLICATION NUMBER: *PCT/US03/29875*

CERTIFIED COPY OF PRIORITY DOCUMENT

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PTO/SB/16 (10-01)
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No.

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Eugene Ben	Silverman	Ellicott City, MD
Richard	Skallos	Severna Park, MD

☐ *Additional inventors are being named on the _____ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

BROADBAND LONG PULSE UNTRASONIC INSPECTION

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

[x] Customer Number: 30678 (*Customer Number*) → *Customer Number Bar Code*

OR

☐ Firm or Individual Name					
Address					
City		State		Zip	
Country		Telephone		Fax	

ENCLOSED APPLICATION PARTS (*check all that apply*)

- [x] Specification *Number of Pages* 14
- [x] Drawing(s) *Number of Sheets* 4
- ☐ Application Data Sheet. See 37 CFR 1.76
- ☐ CD(s), Number
- ☐ Other:

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

- [x] Applicant claims small entity status. See 37 CFR 1.27.
- ☐ A check or money order is enclosed to cover the filing fees
- [x] The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: 22-0185
- ☐ Payment by credit card. Form PTO-2038 is attached.

FILING FEE AMOUNT ($): 80.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

[x] No ☐ Yes, the name of the U.S. Government agency and the Government contract number are:

Respectfully submitted,

SIGNATURE: Stanley B. Green

Date: September 24, 2002

TYPED OR PRINTED NAME: Stanley B. Green

REGISTRATION NO. (*if appropriate*): 24,351

TELEPHONE: (202) 331-7111

Docket Number: 06452-00006-US

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

222846

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09/24/02 U.S. PTO

60/412778 .092402

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FEE TRANSMITTAL for FY 2002

Patent fees are subject to annual revision.

☐ Applicant claims small entity status. See 37 CFR 1 27

TOTAL AMOUNT OF PAYMENT ($) 80.00

Complete if Known	
Application Number	Not Yet Assigned
Filing Date	September 24, 2002
First Named Inventor	Eugene B. Silverman
Examiner Name	Not Yet Assigned
Group Art Unit	N/A
Attorney Docket No.	06452-00006-US

METHOD OF PAYMENT (check all that apply)

☐ Check ☐ Credit Card ☐ Money Order ☐ Other ☐ None

☒ Deposit Account

Deposit Account Number: 22-0185

Deposit Account Name: Connolly Bove Lodge & Hutz, LLP

The Commissioner is hereby authorized to: (check all that apply)

☒ Charge fee(s) indicated below ☒ Credit any overpayments

☒ Charge any additional fee(s) during the pendency of this application

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to the above-identified deposit account

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	740	201	370	Utility filing fee	
106	330	206	165	Design filing fee	
107	510	207	255	Plant filing fee	
108	740	208	370	Reissue filing fee	
114	160	214	80	Provisional filing fee	80 00

SUBTOTAL (1) ($) 80 00

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

			Extra Claims		Fee from below		Fee Paid
Total Claims		-** =		x		=	
Independent Claims		-** =		x		=	
Multiple Dependent						=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	84	202	42	Independent claims in excess of 3
104	280	204	140	Multiple dependent claim, if not paid
109	84	209	42	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 0 00

**or number previously paid, if greater; For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge – late filing fee or oath	
127	50	227	25	Surcharge – late provisional filing fee or cover sheet.	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for *ex parte* reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	400	216	200	Extension for reply within second month	
117	920	217	460	Extension for reply within third month	
118	1,440	218	720	Extension for reply within fourth month	
128	1,960	228	980	Extension for reply within fifth month	
119	320	219	160	Notice of Appeal	
120	320	220	160	Filing a brief in support of an appeal	
121	280	221	140	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive – unavoidable	
141	1,280	241	640	Petition to revive - unintentional	
142	1,280	242	640	Utility issue fee (or reissue)	
143	460	243	230	Design issue fee	
144	620	244	310	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Processing fee under 37 CFR 1 17(q)	
126	180	126	180	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	740	246	370	Filing a submission after final rejection (37 CFR 1 129(a))	
149	740	249	370	For each additional invention to be examined (37CFR 1.129(b))	
179	740	279	370	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	

Other fee (specify)

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 0 00

SUBMITTED BY

				Complete (if applicable)	
Name (Print/Type)	Stanley B. Green	Registration No. (Attorney/Agent)	24,351	Telephone	(202) 331-7111
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09/25/2002 JBALIAN 00000011 220185 60412778
Sale Ref: 00000043 DAH: 220185 60412778
01 FC:214 80.00 CH

Docket No: 6452-6

BROADBAND LONG PULSE ULTRASONIC INSPECTION

Field of the Invention

The invention relates to the ultrasonic inspection of materials, particularly walls of fluid reservoirs and the like.

Background of the Invention

Traditional non-destructive testing of ferrous metals using ultrasound (UT) is typically accomplished with pulse sources that stimulate the plate under test. The vibrations from the mechanical displacement of the surface of the transducer are transmitted into the test material which, in turn, causes a displacement of the test area directly underneath the transducer. The vibrations set-up in this area are "reflected" back to the same transducer. These reflections can be simple or complex depending on whether there are defects or discontinuities in the plate. The UT electronics compute the difference in time between the outgoing UT vibrations and those that return to the face of the transducer. The difference in the timing between the outgoing and incoming vibrations is used to calculate test specimen thickness and defects such as pits.

The industry has long been aware of the need to inspect the walls of fluid reservoirs, particularly when those walls are metal. In this application, the term "walls" refers to both bottom and side walls of a structure or tank. Special problems are engendered when the fluid maintained in the reservoir is combustible.

One solution to the problem is the technology described in Silverman patent 5,205,174. This patent describes a robotic vehicle which can travel into a partly filled fluid reservoir and traverse the tank for inspection. The '174 patent describes both optical and ultrasonic inspection technologies.

Due to the limited bandwidth of ultrasonic transducers and their short pulses, reasonable signal to noise ratios are difficult to maintain (a 5 MHz pulse is 200 nsec wide). That is, the greater the time-bandwidth product, the greater amount of signal (and therefore, the greater amount of information) is returned relative to background noise. Additionally, threshold techniques are used with pulse-echo signals which work well with high signal-to-noise ratios, but produce false alarms with low signal-to-noise ratios that are common within the NDT environment of interest.

A particular problem in tanks storing combustible fluids is that the inspection system must first travel through a region devoid of the fluid before traveling into the fluid containing region in order to reach the wall to be inspected. Traversing the fluid-free regions is a problem because when the reservoir stores combustible fluid, the fluid-free region typically contains combustible vapors.

Standards bodies have devised standards for instruments which work or travel through regions containing combustible vapors. Limitations on the voltage and current levels found on apparatus in the combustible region allows that apparatus to be considered "intrinsically safe".

On the other hand, limiting the inspection system to voltage and current levels which are below the thresholds established in these standards presents problems in conducting an effective inspection.

Summary of the Invention

Thus the present invention is directed at improved ultrasonic inspection methodology for inspecting the walls of fluid reservoirs. The inspection system of the invention is capable of safely inspecting tanks storing combustible fluids.

An alternate way to interrogate material is to determine the transfer function by insonifying the material continuously with a range of frequencies across a specific bandwidth over a finite period of time. The bandwidth and pulse duration is determined by what best represents the degree of resolution necessary to determine the integrity of the material (such as material thickness, or the depth of a pit). The returned signal represents the system transfer function of the liquid-to-material interface and the material itself. The returned system transfer function is then subtracted from a calibration signal that represents the normal response of the transducer from a calibration block. The subtraction process is completed through simply correlating the received signature from the signature derived from the calibration material. The front face return (liquid-to-material interface) can be adaptively subtracted from the received signal, leaving the material data. Further analysis can be conducted on the test material in order to identify other characteristics of importance (discontinuities, corrosion, etc.).

Unique characteristics associated with the use of long pulse chirp signals for NDT applications within an in-service robotic operational environment include:

1. Combined use of a chirp signal with signal correlators to determine material transfer functions.
2. Chirp signals can be produced with significantly lower power than traditional pulse-echo signals which lends itself to use in environments that are potentially explosive.
3. The use of a chirp bandwidth of low frequency is less susceptible to the influences of sludge interference as compared to single, high frequency pulse-echo transducers.
4. A wider variety of transducer electro-mechanical characteristics can be applied to a wider range of materials in order to interrogate unique material features.
5. When combined with in-service robotic system used to examine the integrity of aboveground storage tank floors within highly volatile environments, signals can be made intrinsically safe.

Accordingly, in one respect the invention provides an ultrasonic inspection system for inspecting walls of fluid reservoirs comprising a robotic vehicle;

a transducer supported on the robotic vehicle and responsive to electrical energy for emitting corresponding sonic energy in a chosen direction,

a support for the transducer on the robotic vehicle positioning the transducer so the chosen direction is broadside to a selected wall of fluid reservoir,

a drive circuit energizing the transducer with a broadband electrical pulse of duration in excess of that necessary for the sonic energy to transit the selected wall from one face to another, and

an amplifier coupled to the transducer for receiving the signal from the transducer in response to sonic energy received from the selected wall.

In preferred embodiments the broadband electrical pulse includes energy up to about 10 MHz, for certain other application energy up to about 5 MHz may be used and in still other embodiments we may restrict energy to about 3.5 MHz.

More particularly, the ultrasonic inspection system includes an array of transducers, each transducer in the array supported to have chosen directions which are substantially parallel wherein the drive circuit and the energizes each transducer with the broadband electrical pulse of substantially identical duration but offset in time from one another and wherein the amplifier has a separate channel for each transducer in the array.

The ultrasonic inspection system further includes control means for de-energizing the drive circuit predetermined time after initiation of the broadband electrical pulse.

In connection with another aspect, the inspection instrument includes a gated drive circuit, more particularly, a gated drive circuit which is gated off at the termination of the inspection pulse. In particular, the drive circuit for inspection system for ultrasonic inspection using a long broadband inspection pulse includes a receiver for receiving a long broadband inspection pulse,

a gated amplifier coupled to said receiver with an output connected to an ultrasonic transducer for driving in the transducer with an amplified replica of said inspection pulse, and

control means responsive to control data for controlling de-energization of the gated amplifier in response to said control data,

whereby material under test adjacent to said transducer is subjected to ultrasonic energy produced by said transducer driven by said amplified inspection pulse.

In a particular aspect of the invention the gated amplifier includes an electronic amplifier coupled to an output of the receiver, a control switch, and a step-up converter coupled between the output of the controlled switch and the transducer.

In a further particular aspect of the invention the up converter comprises a transformer.

A further aspect of the invention relates to the extension of intrinsic safety. In this aspect electrical parameters for equipment within a combustion prone region are limited to levels at or below what is considered intrinsically safe. However, in order to efficiently conduct an inspection regime, allowance is made for electrical parameters to be increased beyond the intrinsically safe level but only for apparatus which is indicated to be outside the explosion prone region.

More particularly, the inspection apparatus includes a converter for increasing electrical energy parameters beyond an intrinsically safe level. The up converter, however, is only operated in response to an enabling signal. Production of the enabling signal requires an indication that at least some of the inspection apparatus is positively identified as being outside the explosion prone region. More particularly, an indication must be received that the inspection apparatus lies within a liquid environment.

This is implemented by maintaining one or more pressure switches on the inspection vehicle. In an initial phase of operation the inspection vehicle travels from outside the tank to be inspected, through the vapor region (which is combustion prone) and into the liquid environment. The converter which enables increase of electrical parameters beyond intrinsically safe levels is carried aboard the inspection vehicle. The inspection vehicle also includes a pressure switch which provides an indication (carried back to a control station via the umbilical) to indicate that the vehicle is within a liquid filled environment. Only which that control signal is received at the control location is a further control signal generated which, when received back at the inspection vehicle, will allow the up converter to be energized.

Thus in accordance with this aspect the invention comprises an inspection vehicle obtaining power from umbilical for operation in a liquid environment in the vicinity of a combustion prone region, the vehicle comprising:

a junction box coupled via said umbilical to a source of electrical energy having at least one electrical energy parameter within an intrinsically safe limit,

a converter coupled to said junction.box for increasing said at least one electrical energy parameter beyond said intrinsically safe limit, and

a sensor for detecting the environment immediately surrounding said vehicle to allow operation of said converter only if said sensor indicates that said vehicle is within said liquid environment.

In accordance with a more specific aspect the sensor responds to pressure surrounding the inspection vehicle to allow operation of the converter only if the sensor detects pressure surrounding the inspecting vehicle indicating that the vehicle is submerged in said liquid environment.

In an even more specific aspect the invention provides an inspection system including the inspection vehicle as aforesaid and a power and signal source driving the umbilical the inspection vehicle including:

a logic device for generating a control signal in response to a permissive signal from said power and signal source.

In other respects the invention describes improvements in ultrasonic inspection for materials in the form used as the walls of fluid reservoirs. More particularly, the walls of fluid reservoirs are typically of metal, which have a thickness which is substantially smaller than any other dimensions of the walls.

Brief Description of the Drawings

The invention will be further described in the following portion of the specification when taken in conjunction with the attached drawings in which like reference characters identify identical apparatus and in which;

Figure 1 is a schematic illustrating the robotic vehicle which carries the inspection system of the invention in a typical operating environment;

Figure 2 is a block diagram of the inspection system and the location of the various components during normal operation;

Figure 3 is a block diagram of the inspection system itself; and

Figure 4 illustrates a typical wave form used to drive the portion of the inspection system carried aboard the robotic vehicle.

Detailed Description of a Preferred Embodiment

As indicated, figure 1 illustrates the typical environment within which the ultrasonic inspection system of the invention operates.

As shown in figure 1, a fluid reservoir 100 is partially filled with fluid having an upper surface 110. The upper surface of the fluid 110 then separates the reservoir 100 into a liquid-filled region L and a vapor-filled region V. A robotic vehicle 10 is located within the tank 100 adjacent to the bottom wall 101. The robotic vehicle 10 is powered so that it can navigate about the tank 100. Typically the robotic vehicle 10 is remotely controlled such as from the remote control location 200. Control signals and power (electric, hydraulic, etc.) are conveyed from a remote location 200 to the robotic vehicle 10 via the umbilical U. The umbilical U also carries signals from the robotic vehicle 10 back to the control location 200.

In typical use the robotic vehicle 10 is introduced into the reservoir 100 adjacent to its upper surface and navigates through the vapor region V and into the liquid region L prior to initiating an examination of the wall of the reservoir, such as the wall 100. The robotic vehicle 10 may be remotely controlled from the remote control 200. The robotic vehicle 10 includes circuitry, power conditioning electronics and the like. Visible from its exterior shape is, the transducer array T. The array T is supported so that each of the transducers (T1, T2, etc.) in the array T may launch sonic energy toward the wall 100 in the direction of the arrow 12. When the sonic energy impinges on the wall 101 it will be reflected by each of the discontinuities in the wall including at least the front face (closest to the vehicle 10 in the direction of the arrow 12) and the rear face (the face further from the vehicle 10 in the direction of the arrow 12) as well as any defects or discontinuities between the front face and the rear face. The reflected energy is converted by the

transducers in the transducer array T from sonic to electrical energy to create a return signal or signature. This return signal is the result of the inspection process. The return signal can be further analyzed using correlation to discern particular features of the wall region that was inspected. The sonic energy emitted from the transducer array T is generated in response to a long, broadband inspection pulse conveyed from the remote control 200 to the vehicle via the umbilical U at the appropriate time. As will be described the inspection pulse is distributed to each of the transducers in a time offset manner. When enabled an up converter, provided for each of the transducers, increases at least one parameter of the pulse so as to more efficiently carry out an inspection. The transducers may be obtained from Krautkramer or Panametrics. At the termination of each inspection pulse at each transducer the drive circuit is cut off by the removal of a gating signal so as to prevent noise generated in the amplifier from corrupting the returned signal.

Figure 2 is a block diagram illustrating the functional relationship between the apparatus in the remote control unit 200 and important components of the robotic vehicle 10, particularly the components directed at the ultrasonic inspection system. In respect of motive power and control of the path of travel of the robotic vehicle 10 reference is made to the Silverman patent 5,205,174.

As shown in figure 2, the remote control unit 200 includes components driving the electrical signal carrying conductor components of the umbilical U. The umbilical U couples the remote control 200 to the robotic vehicle 10 traversing from the exterior of the tank through the vapor region V into the liquid region L.

The umbilical U carries electrical energy to power the ultrasonic inspection components of the robotic vehicle 10, it carries an electrical representation of the return signal from the transducers back to the remote control 200 for processing and it carries additional control and safety signals both from the remote control 200 to the vehicle 10 and from the vehicle 10 to the remote control unit 200.

As will be described, the digital control 290 provides signals to the transmit barrier 230 which are passed along to the inspection system to drive the ultrasonic inspection apparatus. In addition, the return signal is received at the barrier 230 and passed along to the digital control 290 for later analysis.

As shown in figure 2 at the remote control unit 200, power is applied to a power enable gate 210. The safety pressure switch barrier 220 allows power to be applied when appropriate, as will be explained.

Power and control signals flow from the safety pressure switch barrier 220 to the transmit receive barrier 230.

The robotic vehicle 10 includes, in connection with the inspection system, a junction box 240, an explosion proof enclosure 250, a safety pressure switch 260 and the ultrasonic transducer array T. As is shown in figure 2, the transducer array T is made up of a number of individual transducers. In the embodiment shown in figure 2 four transducers T1-T4 comprise the transducer array T. It should be apparent that the number of transducers in the array can be varied within wide limits including using a single transducer to using more than four transducers in the array. As is suggested by the illustration of figure 2, the longitudinal axis of the ultrasonic transducers in the array T may be staggered in the direction of travel of the vehicle 10 so that by sequentially energizing different ones of the transducers in the array T, a swath of the path traveled by the robotic vehicle 10 can be inspected. Alternatively, the transducer may be aligned crosswise to the path of travel of the vehicle 10.

As has been mentioned, the voltage and current levels on the umbilical U are maintained below intrinsically safe levels as mandated by standards. It is an advantage of the invention that these electrical parameters can be increased at the robotic vehicle 10 for efficient generation of ultrasonic inspection energy. To maintain an intrinsically safe system, there should be no increase in the current or voltage parameters on any portion of the system which is in or adjacent to the combustion prone region V. To this end, an

explosion-proof enclosure 250 is provided on the vehicle 10 within which current and/or voltage parameters may be increased without compromising intrinsic safety. The ability to increase voltage and/or current is limited to times during which the vehicle 10 is outside the vapor region V, for example, when vehicle 10 is within the liquid environment L and not within the vapor environment V. This condition is detected by the pressure switch 260. More particularly, the pressure switch is arranged to provide an indication that it is safe to allow increases in voltage and/or current levels within the explosion-proof enclosure 250. This safe indicator is postponed until the vehicle 10 is sufficiently within the liquid environment L so that the risk of combustion is minimal. For example, the pressure switch can be arranged to produce an indication of safety when the vehicle is three feet or more below the surface 110 of the liquid region L. As will be described, the safety indication generated by the safety pressure switch 260 is transmitted back via the junction box 240 and the umbilical U to the power enable element 210 of the safety pressure switch barrier 220. This condition generates a control signal which will be used by the transmit receive barrier 230 in a manner to be described. In one embodiment, electrical parameters in the system both in the umbilical U as well as in the vehicle 10 are normally limited to intrinsically sale levels. Only within the enclosure 250 is it possible to increase electrical parameters above intrinsically safe levels. However, a control signal from the power enable 210 is required to be received at the enclosure 250. This control signal is not generated until the pressure switch 260 indicates that the vehicle is safely within the liquid environment L.

Figure 3 shows a block diagram of the components generating a drive signal for the transducers of the transducer array T. The equipment shown in figure 3 is maintained within the explosion-proof enclosure 250.

Referring now to figure 3, the drive circuit for the transducers in the array T includes a receiver 305 which is driven by the transmit pulse output of the junction box 240 from the umbilical U. The receiver 305 also receives an input enable control signal from the gate array 380. The output of the receiver is fed through amplifier 310 to the per transducer circuitry 315. Circuitry 315 includes a switch 320, an up converter 330

and a preamplifier 340 for each of the transducers in the array T. The switch 320 also receives a selection control signal from the gate array 380. When enabled, the switch 320 provides an output to the up converter 330 which in a preferred embodiment is a transformer. The output of the transformer 330 is coupled to the associated transducer in the transducer array. The transducer output (i.e., the return signal) is coupled in turn to a preamplifier 340 which is connected to a multiplexer 350. The multiplexer 350 also receives a control signal from the gate array 380. The output of multiplexer 350 is applied to the programmable amplifier 360 which also receives an enable signal from the gate array 380. The output of the PGA 360 is coupled to a driver 370 which also receives an output enable signal from the gate array 380. Finally, the output of the driver is coupled through the junction box 240 back unto the umbilical U and thereby connected back to the transmitter receive barrier 230 for further processing.

The programmable gate array 380 implements two programmable functions. As has been indicated there are a number of transducers in the array T. In addition, there is a per-transducer circuit 315 for each transducer in the array. The programmable gate array 380 staggers the engerization and deenergization of each of the transducers by sequentially enabling and then disabling the transducers in turn. The order in which the transducers are enabled and the duration of the enablement and the time at which they are disabled is controlled by the gate array 380 in response to data received from the remote location, as will be described. At this point it is worthwhile noting that the gate array 380 provides a transmit select signal for each switch 320. The transmit select signal goes active, enabling the switch 320 when the corresponding channel is to be enabled. Likewise, the transmit select signal goes low to disable the switch 320 at the termination of the transducer energization.

A second function for the programmable gate array is gain control for the programmable amplifier 360. In this fashion the output level of the return signal can be adjusted, on the fly, by adjusting the control signal to vary the programmable gain of the amplifier 360.

Finally, a third function is to enable the receiver 305. As has been noted, the array of signals is generated by the gate array 380 in response to data received from the remote location 200 via the umbilical U. The various enabling and select signals are produced only when the rewrite control 200 has received a safe indication from the pressure switch.

At this point reference is made to figure 4 to show the form of the signal which is received at the explosion-proof enclosure 250 during typical operation. As shown in figure 4, the signal has two components. The signal includes a first region A which is occupied by a multi-element control signal. The control signal in this region includes NRZ data for the gate array 380. This data produces the control signals which are required to enable and disable various components shown in figure 3.

As shown in figure 4 the signal also includes a broadband long excitation pulse B which is used to create the sonic pulse for inspection of the tank walls. The inspection pulse has two important characteristics in a preferred embodiment.

In the first place it is referred to as a "long" pulse. This means that the duration of the pulse, (in a preferred embodiment 50 microseconds) is long relative to the time expended by the sonic energy traversing the inspection path, i.e., the gap from transducer to the material to be inspected and then the material to be inspected. For example, the propagation time for one inch thick steel wall is about 35-40 microseconds. Thus a pulse longer than 35-40 microseconds is considered a "long" pulse if used in the inspection of material where the wall thickness and gap together constitute less than one inch.

Another characteristic of the pulse is that it is broadband, e.g., the bandwidth in a preferred embodiment is 3.5 MHz or 5 MHz. In general, the higher the bandwidth, the better the signal to noise ratio. On the other hand, when working in environments which include sludge and high corrosion, there is an impetus to keep the frequency low in order to reduce the effects of sludge and surface roughness. Thus in a preferred embodiment, the bandwidth is preferably 3.5 MHz. Moreover, in a preferred embodiment, the input

pulse is frequency swept so that it might be referred to as a chirp signal. The pulse of fig. 4 may be a 3.5 MHZ chirp with components from 0.5 to 4.5 MHz, an equalization slope to approximate the inverse of the transducer response with 10% cosine weighting.

Another important parameter is the gap, s (see fig. 1) between the material subject to inspection and the forwardmost point of the transducer (T1, T2, etc.), i.e., how far does the sonic energy travel through the liquid environment before impinging on the material subject to inspection. Although some workers sought to minimize the gap s, we have found that there are some benefits from increasing this parameter. In a preferred embodiment for the inspection of metal walls of tanks we presently believe that a gap s of in the range of about 1-3" is preferable.

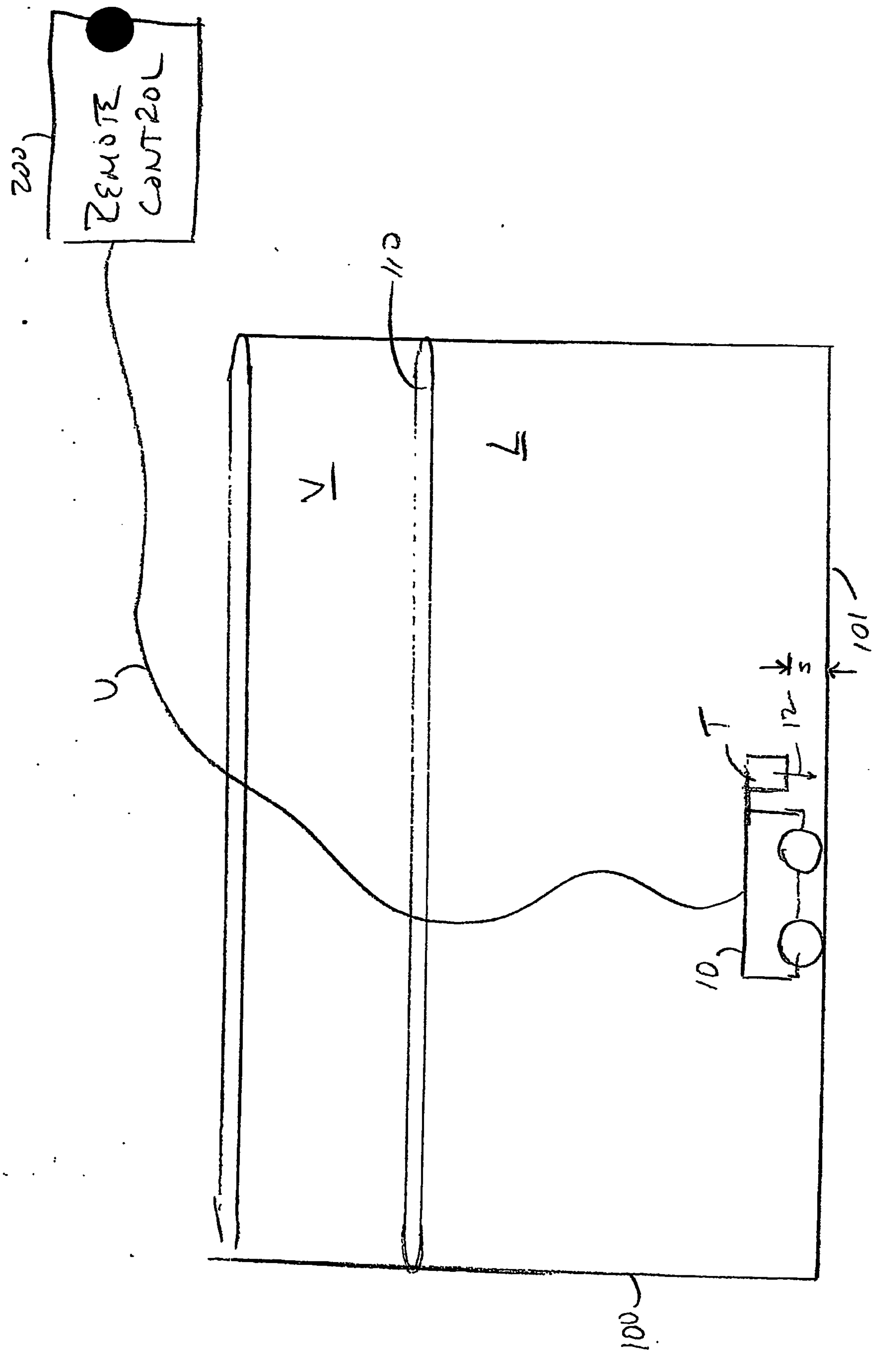
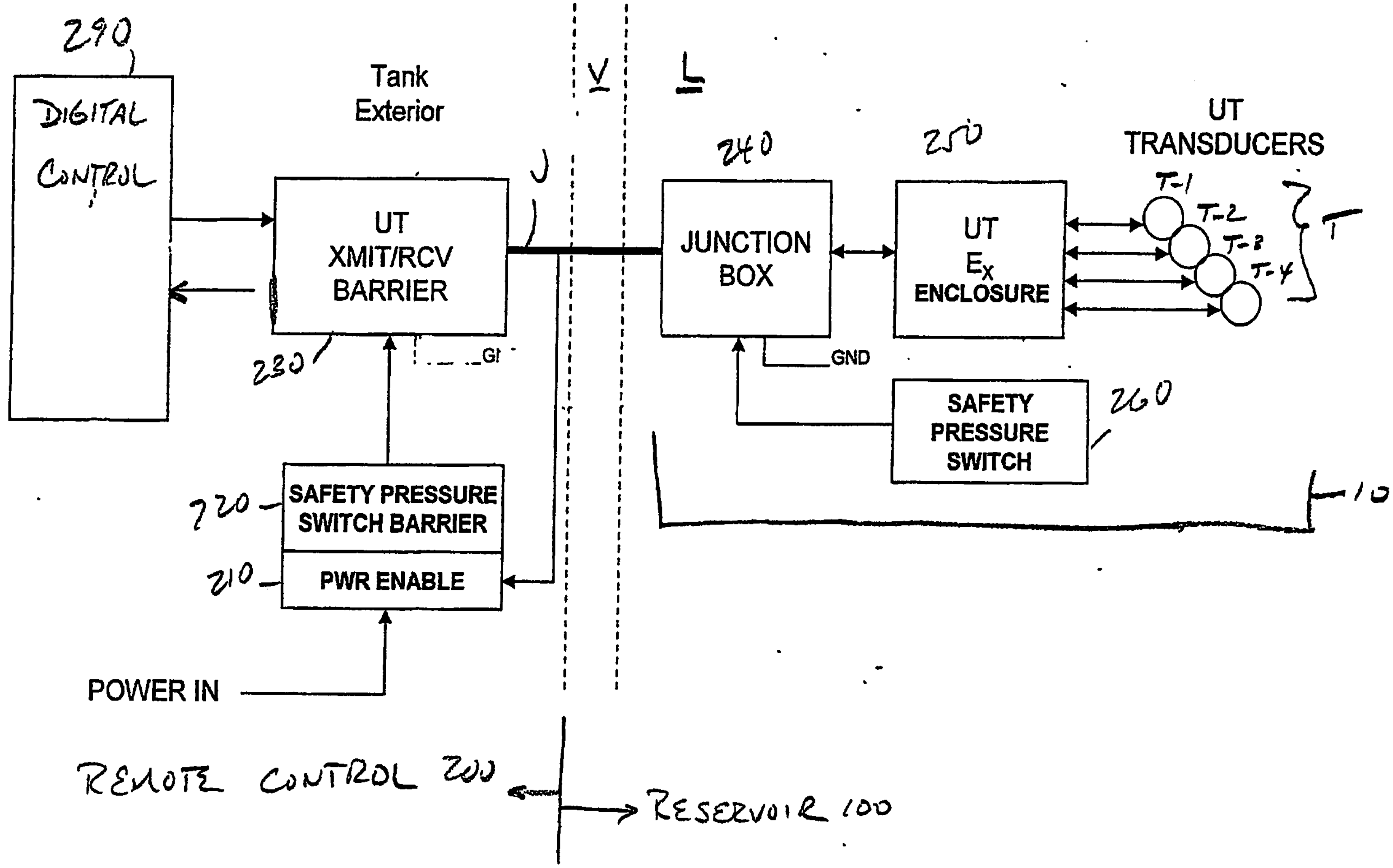


FIG 1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SAFETY PRESSURE SWITCH BARRIER
220
PWR ENABLE
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POWER IN
J
V
L
240
JUNCTION BOX
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UT E_X ENCLOSURE
UT TRANSDUCERS
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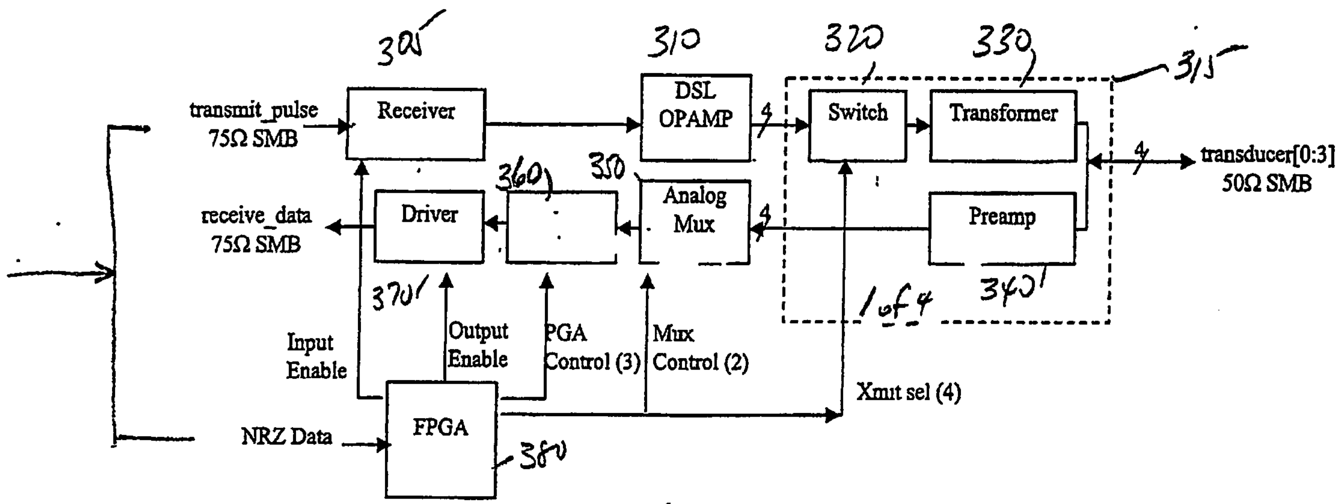
FIG 2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Analog
Mux
4
Preamp
370
1 of 4
340
Input
Enable
Output
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Control (2)
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NRZ Data
FPGA
380

FIG 3

AA1

A1

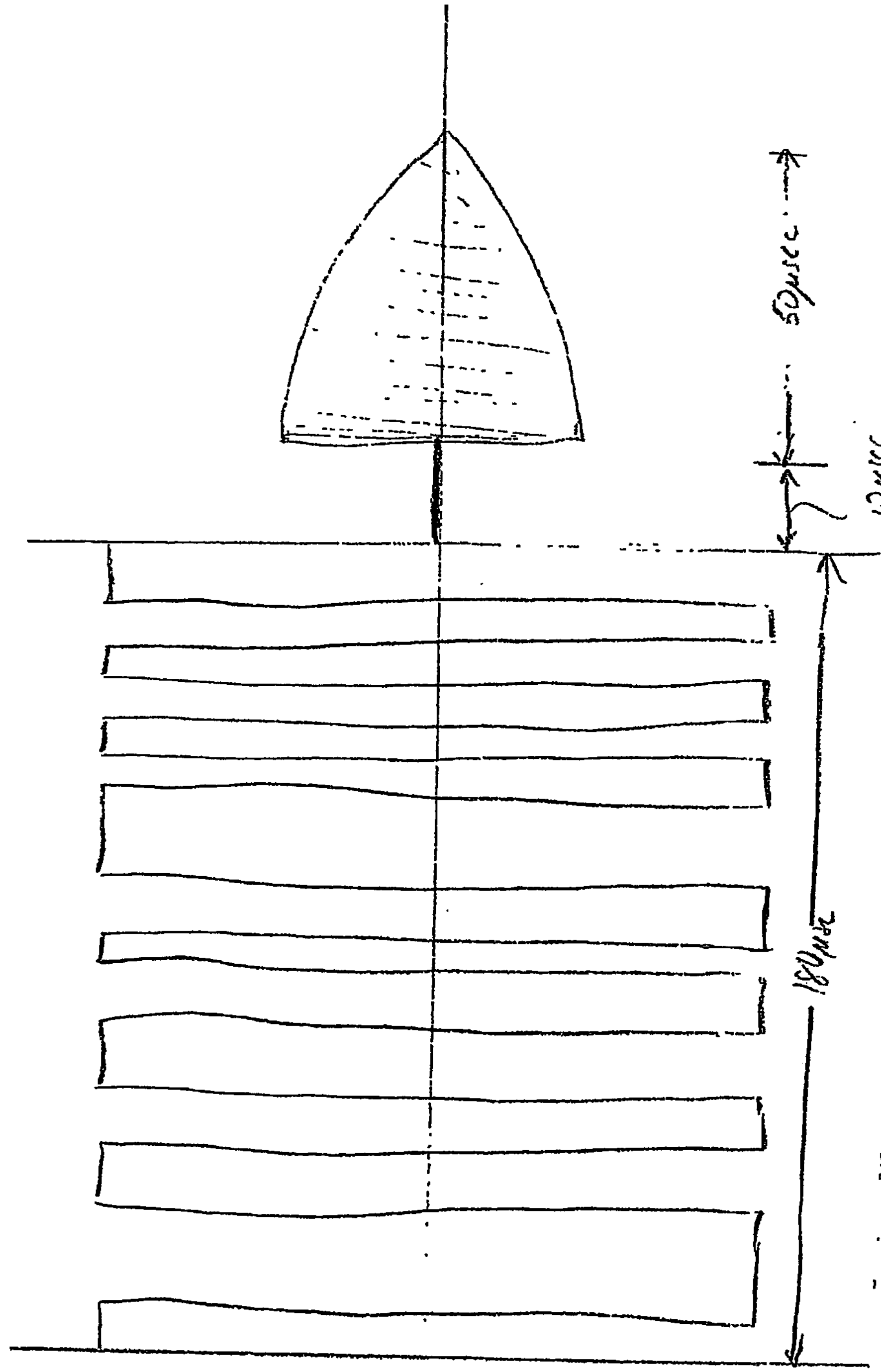

FIG 4